MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

ETM3086 – MOBILE AND SATELLITE COMMUNICATIONS

(TE)

10 MARCH 2017
9.00 A.M. – 11.00 A.M.
(2 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of 10 pages with 4 Questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Two popular frequencies used by the GSM cellular network technology are the 900 MHz and 1800 MHz bands. Suppose a base station transmits 50 W of power.

(i) Express the transmit power in units of dBm and dBW.

[2 marks]

(ii) If the transmit power is applied to a unity gain antenna with a 900 MHz carrier frequency, what is the received power in dBm at a free space distance of 100 m, assuming a unity gain receiver antenna? What is the received power in dBm with a carrier frequency of 1800 MHz, always at a free space distance of 100 m, with unity gain antennas?

[2+2 marks]

(iii) Repeat (ii) for a distance of 10 km.

[2+2 marks]

(iv) Repeat (ii) for a distance of 10 km and the carrier frequency of 900 MHz, but assume a receiver antenna gain of 8dBi and a transmitter antenna gain of 1dBi.

[2 marks]

(v) Based on (ii), provide a possible reason for which the 900MHz spectrum is usually much more attractive to obtain by the mobile network operators than the 1800 MHz spectrum, especially in a country such as Malaysia.

[2 marks]

(b) Mobile radio signals undergo a variety of alterations as they travel from transmitter to receiver. List the four classes of these alterations.

[4 marks]

(c) The US Digital Cellular TDMA system uses a 48.6 kbps data rate to support three users per frame. Each user occupies two of the six time slots per frame. Each reverse channel frame contains six time slots with 324 bits per time slot. Within each time slot, there are 6 guard bits, 6 bits reserved for ramp-up, 28 synchronization bits, 12 control channel bits, 12 bits for supervisory control signals, and 260 data bits.

(i) What is the raw data rate provided for each user?

(ii) Determine the frame efficiency for the system.

(iii) If half-rate speech coding is used, then six users may be supported within a frame. Determine the raw data rate and frame efficiency for users with half-rate speech coding.

[2+2+3 marks]

Continued...

Question 2

(a) If 30 MHz of total spectrum is allocated for a duplex wireless cellular system and each simplex channel has 10 kHz RF bandwidth, find:

(i) the number of duplex channels.

[2 marks]

(ii) the total number of channels per cell site, if N = 3 cell reuse is used.

[2 marks]

(b) (i) How many users can be supported for 0.5% blocking probability for the following number of trunked channels (C) in a blocked calls cleared system? (a) C=5 (b) C=10, Erlang chart provided in Appendix III. Assume that blocked calls are cleared and each user generates 0.1 Erlangs of traffic.

[3+3 marks]

(ii) A function *ErlangB*(m,A) is defined by

$$ErlangB(m, A) = \frac{\frac{A^m}{m!}}{\sum_{k=0}^{m} \frac{A^k}{k!}}$$

where m is the number of identical parallel resources servers, telephone lines, etc. Why is this function useful? How can we use it in designing cellular system?

[4 marks]

(c) In this question, we consider the SIR value when the cluster size N = 1. Sectoring is not used. Suppose this cellular system has only three base stations BS1, BS2 and BS3 respectively. They are marked by triangles located at the centers of three cells in Figure Q2 below. Assume that they transmit the same power level.

Continued...

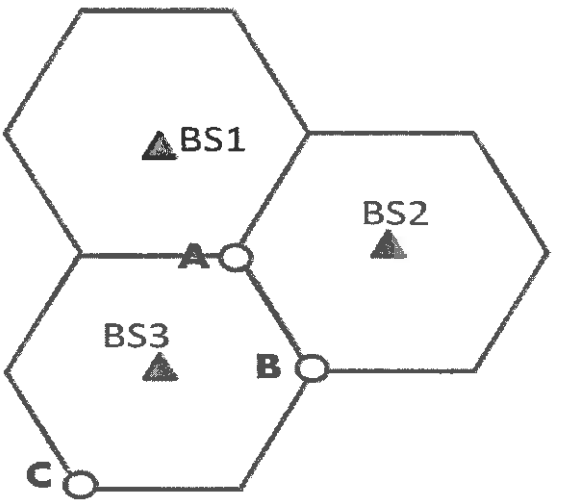

Figure Q2

User A, user B, and user C are currently associated with the lower-left base station (BS3). The locations of these users are marked by the circles in the figure above. The distance from each user to the associated BS is R. Assume a path loss exponent of n=4. Do not approximate distance values.

(i) Find the signal-to-interference ratio (in dB) for user A.

[3 marks]

(ii) Find the signal-to-interference ratio (in dB) for user B.

[4 marks]

(iii) Find the signal-to-interference ratio (in dB) for user C.

[4 marks]

Continued...

Question 3

(a) State TWO advantages and TWO disadvantages of highly elliptical orbit.

[2+2 marks]

(b) With the aid of diagrams, explain the followings:

(i) Vernal Point
(ii) Prograde and Retrograde orbits
(iii)Right Ascension

[3+3+3 marks]

(c) A satellite is launched in an elliptic equatorial orbit opposite to earth's rotation. The eccentricity of the orbit is 0.6 and its period is 10 hours. Find:

(i) The semi-major axis distance.
(ii) The semi-minor axis distance.
(iii)The altitude of the satellite at the apogee point.
(iv)The speed of the satellite at the perigee point.

[2+2+4+4 marks]

Continued...

Question 4

(a) A C-band earth station has an antenna with a transmit gain of 54 dB. The transmitter output power is set to 100 W at a frequency of 6.1 GHz. The signal is received by a satellite at a distance of 37,500 km by an antenna with a gain of 26 dBi. The signal is then routed to a transponder with a noise temperature of 500 K, a bandwidth of 36 MHz, and a gain of 110 dBi

(i) Calculate the path loss at 6.1 GHz. Wavelength is 0.04918 m.

[2 marks]

(ii) Calculate the power at the output port (sometimes called the output waveguide flange) of the satellite antenna, in dBW.

[2 marks]

(iii) Calculate the noise power at the transponder input, in dBW, in a bandwidth of 36 MHz.

[2 marks]

(iv) Calculate the C/N ratio, in dB, in the transponder.

[2 marks]

(v) Calculate the carrier power, in dBW and in watts, at the transponder output.

[2 marks]

(b) The satellite in Question 4(a) above serves the 48 contiguous states of the US. The antenna on the satellite transmits at a frequency of 3875 MHz to an earth station at a distance of 39,000 km. The antenna has a 6° E-W beamwidth and a 3° N-S beamwidth. The receiving earth station has an antenna with a gain of 53 dBi and a system noise temperature of 100 K and is located at the edge of the coverage zone of the satellite antenna. Assume antenna gain is 3 dB lower than in the center of the beam. Ignore your result for transponder output power in Question 4(a) above. Assume the transponder carrier power is 10 W at the input port of the transmit antenna on the satellite.

(i) Calculate the gain of the satellite antenna in the direction of the receiving earth station.
[Use the approximate formula G = 33,000/ (product of beamwidths).]

[3 marks]

(ii) Calculate the carrier power received by the earth station, in dBW.

[4 marks]

(iii) Calculate the noise power of the earth station in 36 MHz bandwidth.

[2 marks]

Continued...

(iv) Hence find the C/N in dB for the earth station.

[2 marks]

(c) Two common multiple access techniques employed in satellite communication systems are Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA). List TWO disadvantages of each technique.

[4 marks]

Continued...

Appendix I: Constant values

Gravitation parameter, μ	=	3.986×10^{14} m^3/s^2
Mean Earth radius, R_E	=	6378 km
Speed of light, c	=	3×10^{8} m/s
Sidereal day	=	23h 56m 4.09s
Boltzmann constant, k	=	1.379×10^{-23} J/K = -228.6 dBW/Hz K

Appendix II: Table of Complementary Error Function

$$erfc(z)=\frac{2}{\sqrt{\pi}}\int_z^\infty e^{-t^2}\,dt \quad \text{for } 0\le z\le 3.99 \text{ in steps of } 0.01$$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000E+00	9.887E-01	9.774E-01	9.662E-01	9.549E-01	9.436E-01	9.324E-01	9.211E-01	9.099E-01	8.987E-01
0.1	8.875E-01	8.764E-01	8.652E-01	8.541E-01	8.431E-01	8.320E-01	8.210E-01	8.100E-01	7.991E-01	7.882E-01
0.2	7.773E-01	7.665E-01	7.557E-01	7.450E-01	7.343E-01	7.237E-01	7.131E-01	7.026E-01	6.921E-01	6.817E-01
0.3	6.714E-01	6.611E-01	6.509E-01	6.407E-01	6.306E-01	6.206E-01	6.107E-01	6.008E-01	5.910E-01	5.813E-01
0.4	5.716E-01	5.620E-01	5.525E-01	5.431E-01	5.338E-01	5.245E-01	5.153E-01	5.063E-01	4.973E-01	4.883E-01
0.5	4.795E-01	4.708E-01	4.621E-01	4.535E-01	4.451E-01	4.367E-01	4.284E-01	4.202E-01	4.121E-01	4.041E-01
0.6	3.961E-01	3.883E-01	3.806E-01	3.730E-01	3.654E-01	3.580E-01	3.506E-01	3.434E-01	3.362E-01	3.292E-01
0.7	3.222E-01	3.153E-01	3.086E-01	3.019E-01	2.953E-01	2.888E-01	2.825E-01	2.762E-01	2.700E-01	2.639E-01
0.8	2.579E-01	2.520E-01	2.462E-01	2.405E-01	2.349E-01	2.293E-01	2.239E-01	2.186E-01	2.133E-01	2.082E-01
0.9	2.031E-01	1.981E-01	1.932E-01	1.884E-01	1.837E-01	1.791E-01	1.746E-01	1.701E-01	1.658E-01	1.615E-01
1.0	1.573E-01	1.532E-01	1.492E-01	1.452E-01	1.414E-01	1.376E-01	1.339E-01	1.302E-01	1.267E-01	1.232E-01
1.1	1.198E-01	1.165E-01	1.132E-01	1.100E-01	1.069E-01	1.039E-01	1.009E-01	9.800E-02	9.516E-02	9.239E-02
1.2	8.969E-02	8.704E-02	8.447E-02	8.195E-02	7.949E-02	7.710E-02	7.476E-02	7.249E-02	7.027E-02	6.810E-02
1.3	6.599E-02	6.394E-02	6.193E-02	5.998E-02	5.809E-02	5.624E-02	5.444E-02	5.269E-02	5.098E-02	4.933E-02
1.4	4.771E-02	4.615E-02	4.462E-02	4.314E-02	4.170E-02	4.030E-02	3.895E-02	3.763E-02	3.635E-02	3.510E-02
1.5	3.389E-02	3.272E-02	3.159E-02	3.048E-02	2.941E-02	2.838E-02	2.737E-02	2.640E-02	2.545E-02	2.454E-02
1.6	2.365E-02	2.279E-02	2.196E-02	2.116E-02	2.038E-02	1.962E-02	1.890E-02	1.819E-02	1.751E-02	1.685E-02
1.7	1.621E-02	1.559E-02	1.500E-02	1.442E-02	1.387E-02	1.333E-02	1.281E-02	1.231E-02	1.183E-02	1.136E-02
1.8	1.091E-02	1.048E-02	1.006E-02	9.653E-03	9.264E-03	8.889E-03	8.528E-03	8.179E-03	7.844E-03	7.521E-03
1.9	7.210E-03	6.910E-03	6.622E-03	6.344E-03	6.077E-03	5.821E-03	5.574E-03	5.336E-03	5.108E-03	4.889E-03
2.0	4.678E-03	4.475E-03	4.281E-03	4.094E-03	3.914E-03	3.742E-03	3.577E-03	3.418E-03	3.266E-03	3.120E-03
2.1	2.979E-03	2.845E-03	2.716E-03	2.593E-03	2.475E-03	2.361E-03	2.253E-03	2.149E-03	2.049E-03	1.954E-03
2.2	1.863E-03	1.776E-03	1.692E-03	1.612E-03	1.536E-03	1.463E-03	1.393E-03	1.326E-03	1.262E-03	1.201E-03
2.3	1.143E-03	1.088E-03	1.034E-03	9.838E-04	9.354E-04	8.893E-04	8.452E-04	8.032E-04	7.631E-04	7.249E-04
2.4	6.885E-04	6.538E-04	6.207E-04	5.892E-04	5.592E-04	5.306E-04	5.034E-04	4.774E-04	4.528E-04	4.293E-04
2.5	4.070E-04	3.857E-04	3.655E-04	3.463E-04	3.280E-04	3.107E-04	2.942E-04	2.785E-04	2.636E-04	2.495E-04
2.6	2.360E-04	2.233E-04	2.112E-04	1.997E-04	1.888E-04	1.785E-04	1.687E-04	1.594E-04	1.506E-04	1.422E-04
2.7	1.343E-04	1.268E-04	1.197E-04	1.130E-04	1.066E-04	1.006E-04	9.492E-05	8.952E-05	8.441E-05	7.958E-05
2.8	7.501E-05	7.069E-05	6.661E-05	6.275E-05	5.910E-05	5.566E-05	5.240E-05	4.933E-05	4.642E-05	4.368E-05
2.9	4.110E-05	3.866E-05	3.635E-05	3.418E-05	3.213E-05	3.020E-05	2.838E-05	2.667E-05	2.505E-05	2.353E-05
3.0	2.209E-05	2.074E-05	1.947E-05	1.827E-05	1.714E-05	1.608E-05	1.508E-05	1.414E-05	1.326E-05	1.243E-05
3.1	1.165E-05	1.092E-05	1.023E-05	9.578E-06	8.970E-06	8.398E-06	7.862E-06	7.358E-06	6.885E-06	6.442E-06
3.2	6.026E-06	5.635E-06	5.269E-06	4.926E-06	4.604E-06	4.303E-06	4.020E-06	3.755E-06	3.507E-06	3.275E-06
3.3	3.058E-06	2.854E-06	2.664E-06	2.485E-06	2.319E-06	2.162E-06	2.017E-06	1.880E-06	1.753E-06	1.633E-06
3.4	1.522E-06	1.418E-06	1.321E-06	1.230E-06	1.145E-06	1.066E-06	9.922E-07	9.233E-07	8.590E-07	7.990E-07
3.5	7.431E-07	6.910E-07	6.423E-07	5.970E-07	5.548E-07	5.155E-07	4.788E-07	4.447E-07	4.130E-07	3.834E-07
3.6	3.559E-07	3.303E-07	3.064E-07	2.843E-07	2.636E-07	2.445E-07	2.267E-07	2.101E-07	1.947E-07	1.804E-07
3.7	1.672E-07	1.548E-07	1.434E-07	1.327E-07	1.229E-07	1.137E-07	1.052E-07	9.736E-08	9.005E-08	8.328E-08
3.8	7.700E-08	7.119E-08	6.579E-08	6.080E-08	5.617E-08	5.189E-08	4.792E-08	4.425E-08	4.085E-08	3.770E-08
3.9	3.479E-08	3.210E-08	2.961E-08	2.731E-08	2.518E-08	2.322E-08	2.140E-08	1.972E-08	1.817E-08	1.674E-08

Note: 1.000E-01 = 1.000×10^{-1}

For $z > 4$, $\quad erfc(z)\approx\frac{1}{\sqrt{\pi}}\left(\frac{e^{-z^2}}{z}\right)$

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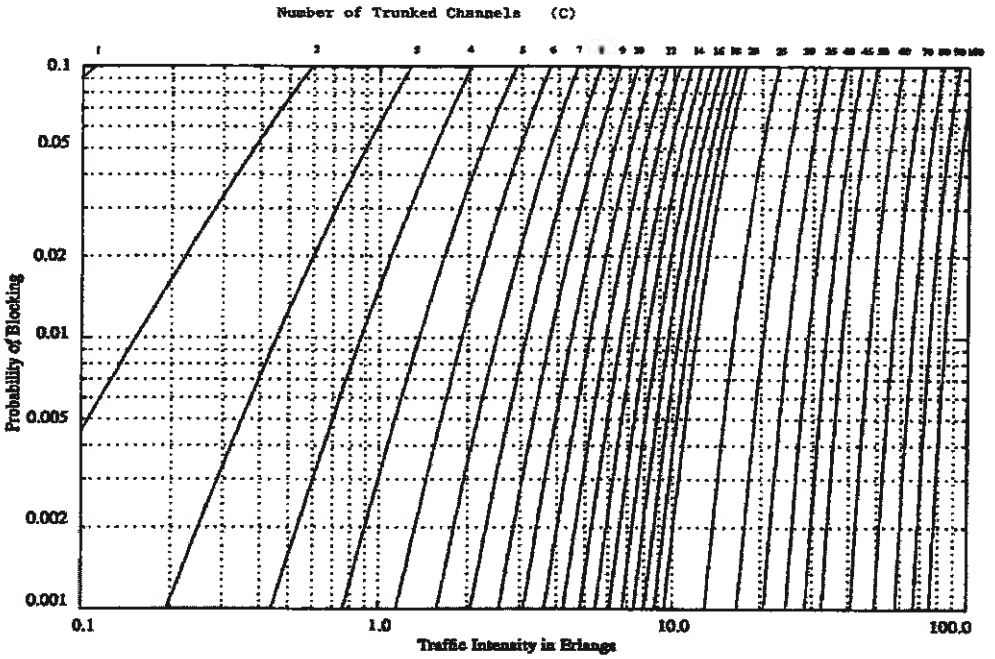
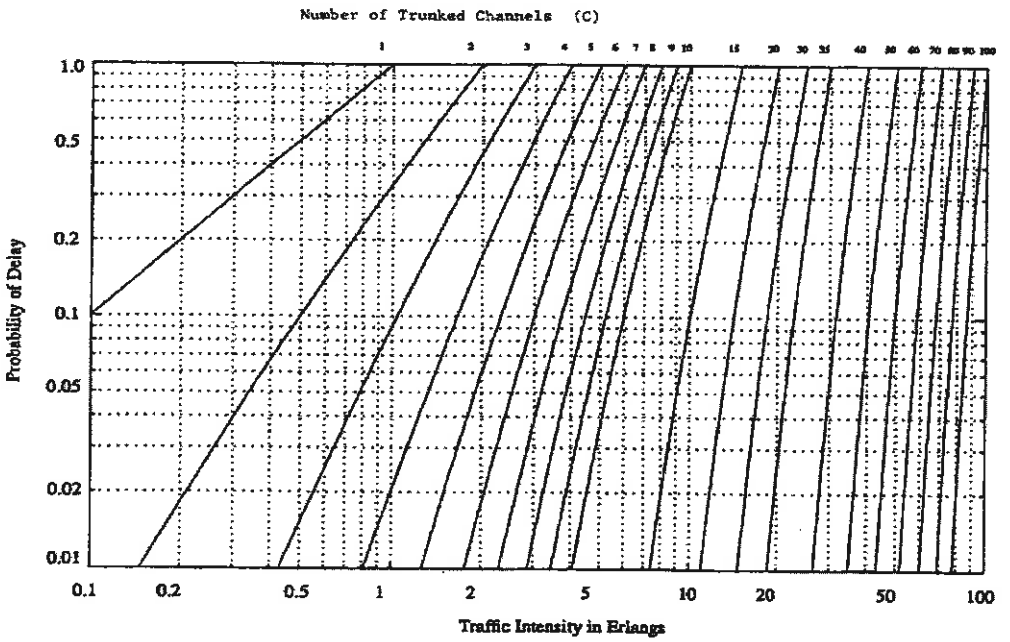
Appendix III: Erlang B and Erlang C Chart



The Erlang B chart showing the probability of blockings as functions of the number of channels and traffic intensity in Erlangs.



The Erlang C chart showing the probability of a call being delayed as a function of the number of channels and traffic intensity in Erlangs.

Continued...

Appendix IV: Formulae

Remarks: The general formulae below may need to be modified according to the context.

$$v_S = \sqrt{\frac{\mu}{a}\left(\frac{2a}{r_o}-1\right)} \quad SIR = \frac{P_r}{\sum_{i=1}^{K} P_i} = \frac{1}{\sum_{i=1}^{K} \frac{1}{\left(\frac{D_i}{R}\right)^n}} \quad T^2 = \frac{4\pi^2 a^3}{\mu} \quad r = \frac{a\left(1-e^2\right)}{1+e\cdot\cos(\theta)}$$

$$b = a\sqrt{1-e^2}$$

Antenna

Effective isotropic radiated power, $EIRP = P_t G_t$

Power flux density, $\phi = \frac{EIRP}{4\pi R^2}$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter D:

$$G_{\max} = \left(\frac{4\pi}{\lambda^2}\right)A_{eff} = \eta\left(\frac{\pi D}{\lambda}\right)^2 = \eta\left(\frac{70\pi}{\theta_{3dB}}\right)^2, \text{ where } \theta_{3dB} = 70\left(\frac{\lambda}{D}\right)$$

Link Analysis

Received power, $[P_r] = [EIRP] + [G_r] - [L_{Total}]$

Free space loss, $L_{FS} = \left(\frac{4\pi R}{\lambda}\right)^2$

Noise power spectral density, $N_o = kT$

Noise factor, $F = 1 + \frac{T_e}{T_o}$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \ldots + \frac{T_{en}}{G_1 G_2 \ldots G_{n-1}}$$

FDM-FM-FDMA Satellite System

Signal bandwidth, $B = 2(gl\Delta f_{rms} + f_{max})$

where $\log_{10} l = \begin{cases} (-1+4\log_{10} n)/20, & n \le 240 \\ (-15+10\log_{10} n)/20, & n > 240 \end{cases}$

Relationship between *C/N* and *S/N* is given by:

$$\frac{C}{N} = \left(\frac{S}{N}\right)\left(\frac{b}{B}\right)\left(\frac{f_{\max}}{\Delta f_{rms}}\right)^2 \frac{1}{pw}$$

End of Paper